Lithium-Ion Batteries for Aerospace Applications

S. Surampudi & G. Halpert
(Jet Propulsion Laboratory, Pasadena, CA)
R. A . Marsh & R. James
(U.S. Air Force Research Laboratory, HQ Air Force Materials Command
Wright Patterson AFB, OH)

Rechargeable lithium ion batteries are projected to offer significant performance and cost benefits for future space missions. The projected benefits include: reduced weight and volume of the energy storage system, improved reliability and low power system life cycle costs. In view of these advantages NASA and US Air Force are considering the use of lithium ion batteries for many next millennium space missions. Some of the projected NASA applications are planetary landers, planetary rovers, planetary orbitters, earth orbitting spacecraft (GEO and LEO) and astronaut equipment. The Air Force is considering use of these batteries in various applications such as unmanned aerial vehicles, military aircraft, and earth orbitting spacecraft(GEO & LEO)

Space applications require 28-100 V, 10-200 Ah batteries capable of providing 1000-2000 cycles at 60-80% depth of discharge or 30,000 at 25-40% depth of discharge. Some of the planetary missions require battery operation at temperatures as low as -40C. Further, these batteries need to meet environmental requirements such as vibration, shock, and high impact. Small capacity lithium ion cells (1-4 Ah) that only provide 500-1000 cycles are presently available commercially. Further, battery packs limited to 2-4 cells are being supplied for consumer applications. State of the art lithium ion cells need improvements in several areas such as cell size/capacity, cycle life, and operating temperature. Further, the performance data base is very limited on the charge management of batteries containing eight or more cells. In addition, safety of large capacity cells/and batteries is also a serious concern.

A joint NASA/ DOD program has been established to develop lithium ion batteries required for future NASA and DOD missions. The specific objectives of this program are : a) improve low temperature performance capability, b) demonstrate long cycle required for GEO and LEO missions, c) develop cells (6-100Ah) and batteries (16-300V) of various sizes required for various future missions, d) develop control electronics for smart battery management, and e) establish manufacturing capabilities in US. These batteries will be initially used in missions where weight and volume are critical and cycle life requirements are low to moderate (500-1000). NASA is considering use of these lithium ion batteries for the first time in Mars 2001 Lander and Rover missions. USAF is considering these advanced lithium ion batteries for use initially in military aircraft and unmanned aerial vehicles. NASA is also planning to use these batteries for Mars 2003, Mars 2005, Champlollion, Solar Probe, and Libration Point Missions. These batteries may also find application in cameras, astronaut equipment, satellite tools etc. As the technology matures, these batteries will be considered for GEO and LEO missions.

Acknowledgments

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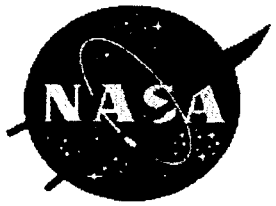

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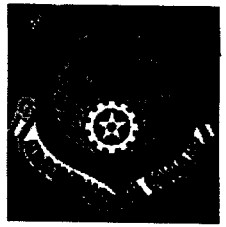

S. Surampudi & G. Halpert

Jet Propulsion Laboratory

Pasadena, CA

R. A . Marsh & R. James

U.S. Air Force Research Laboratory

Dayon, OH/Albuquerque NM

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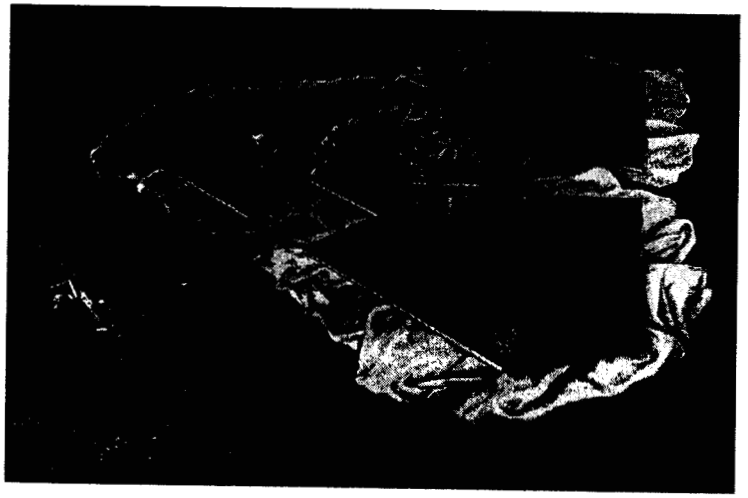
9 th International Li Battery Meeting

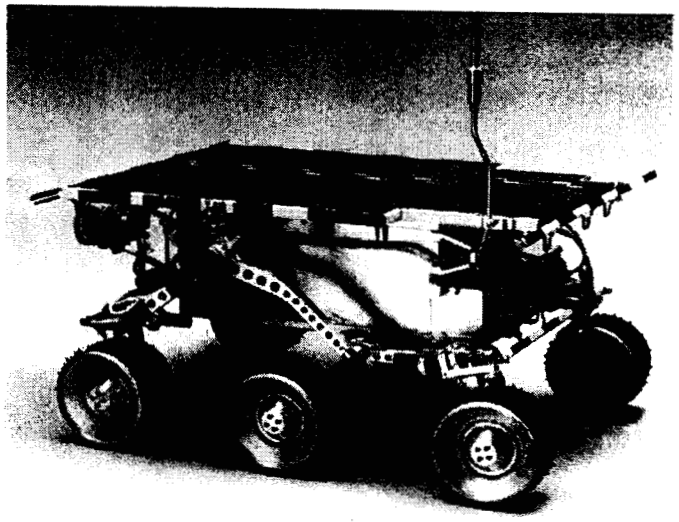
Edinburgh, Scotland

OVERVIEW

- Program Goals
- NASA Mission Requirements
- AF Mission Requirements
- Potential Near Term Missions
- Management Approach
- Technical Approach
- Program Road Map

PLANETARY MISSION BATTERY REQUIREMENTS





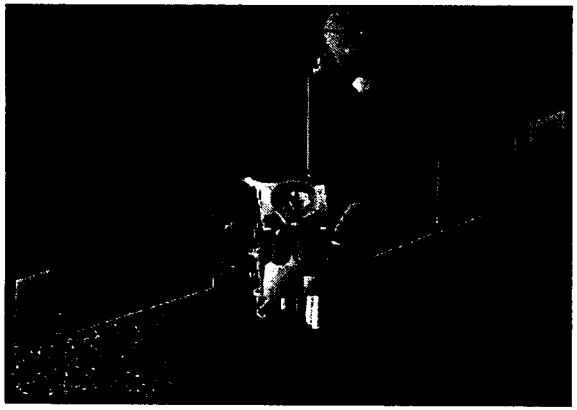
LANDERS

- CAPACITY: 20-40 AH
- VOLTAGE: 28V
- DISCHARGE RATE: C/10-C/5
- > 500 CYCLES (>50%DOD)
- -40 TO 50 C

ROVERS

- CAPACITY: 5-20 AH
- VOLTAGE: 16 V
- DISCHARGE RATE: C/2-C/5
- > 500 CYCLES (>50%DOD)
- -40 TO 40 C

PLANETARY MISSION BATTERY REQUIREMENTS



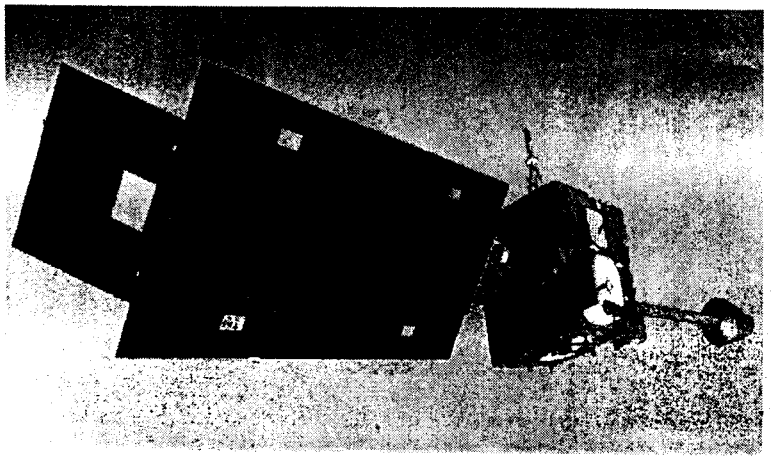
ORBITERS

- CAPACITY: 20-35 AH
- VOLTAGE: 28V
- DISCHARGE RATE: C/2-C
- > 30,000 CYCLES (>25%DOD)
- -5 TO 30 C
- >5 YEARS

PENETRATORS

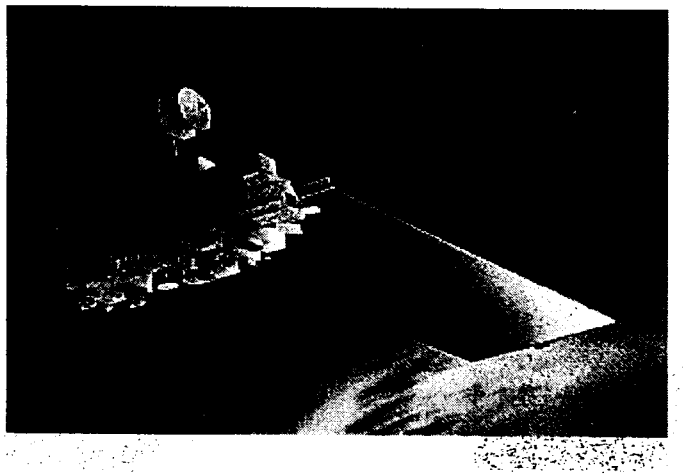
- CAPACITY: 0.5-2 AH
- DISCHARGE RATE: C/100-C/50
- > 300 CYCLES (>70%DOD)
- -80 T0 30 C

EARTH ORBITING MISSION BATTERY REQUIREMENTS



GEO SPACECRAFT

- CAPACITY: 10-35AH
- VOLTAGE: 28-100 V
- DISCHARGE RATE: C/2
- > 2000 CYCLES (>75%DOD)
- -5 TO 30 C
- 10-15 YEARS



LEO SPACECRAFT

- CAPACITY: 10-35 AH
- VOLTAGE: 28 V
- DISCHARGE RATE: C/2-C
- > 30,000 CYCLES (>25% DOD)
- -5 TO 30 C
- >5 YEARS

MISSION REQUIREMENTS

	LANDERS	ROVERS	GEO	LEO/ PLA. ORBITER	S/C TOOLS	LIBRATION POINT S/C
CAPACITY (AH)	20-40	5-10	10, 20, 35	10, 20, 35	3-5 AH	20-25 AH
VOLTAGE (V)	28	28	28-100	28	28	28
DIS. RATE	C/5-1C	C/5-C/2	C/2	C/2-C	C/2	C/2
CYCLE LIFE	> 500 (>60%DOD)	>500 (>60% DOD)	2000 (>75% DOD)	>30,000 (>30% DOD)	>100	50
OPER. TEMP (C)	-40 TO 40	-40 TO 40	-5 TO 30	-5 TO 30	0-50C	25-30
SP. ENERGY (Wh/KG)*	>100	>100	>100	>100	>100	100
ENERGY DENSITY (Wh/l)*	120-160	120-160	120-160	120-160	>80	120-160

* 100% DOD BOL

AIRCRAFT
BATTERY REQUIREMENTS

AIR CRAFT

VOLTAGE: 28-270 V

CAPACITY: 5-20 Ah

DIS. RATE: 1C

CYCLE LIFE: 1000 (50% DOD)

OPER. TEMP: -40TO +65

SP. ENERGY: > 100 WH/KG

UAV'S

VOLTAGE: 28-100 V

CAPACITY: 100-200 Ah

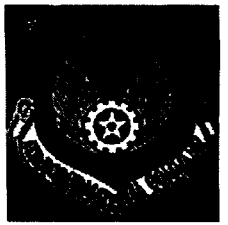
DIS. RATE: C/5 TO 1C

CYCLE LIFE: 1000 (50% DOD)

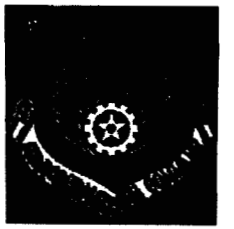
OPER. TEMP: -40TO +65

SP. ENERGY: > 100 WH/KG

DOD Lithium-Ion Battery Performance Requirements



Type	Operating Voltage	Capacity (Ahr)	Temp. (°C)	Cycle Life	Discharge Rate Charge Rate	% DOD
UAVs	100	200	-40 to +65	1000	C C	50
Aircraft (a)	270	20	-40 to +65	1000	C C	50
Aircraft (b)	270	20	-40 to +65	1000	C C	50
GEO Sats	100	50	-5 to +30	1500	2/3 C C/20	75 (max)
LEO Sats	28	50	-5 to +30	45000	C C/2	25



TECHNOLOGY DRIVERS FOR FOR VARIOUS MISSIONS

MISSION	TECHNOLOGY DRIVER
LANDER/ROVER	LOW TEMP. OPERATION HIGH RATE PULSE CAPABILITY
GEO S/C	TEN-TWENTY YEAR OPERT. LIFE LARGE CAPACITY CELLS (50-200 Ah)
LEO/PLANTERARY S/C	LONG CYCLE LIFE (30,000) MED. CAPACITY CELLS (50 Ah)
AIRCRAFT	LOW TEMP OPERATION HIGH VOLTAGE BATTERIES (270 V)
UAV	LARGE CAPACITY CELLS (200 Ah) HIGH VOLTAGE BATTERIES (100V)

OTHER CHALLENGES: RELIABILITY, SAFETY & COST

POTENTIAL NEAR TERM SPACE MISSIONS/APPLICATIONS

•NASA MISSIONS

•JPL

MARS LANDER AND ROVER -2001

MARS LANDER AND ROVER -2003

MARS SAMPLE RETURN MISSION - 2005

CHAMPOLILON MISSION - 2003

SOLAR PROBE - 2005

•GSFC

SATELITE SERVICING TOOLS

LIBRATION POINT SPACECRAFT (MAP-2000,NGST 2007)

GEO SPACECRAFT(GOES)

LEO SPACECRAFT(EOS)

•AIR FORCE MISSIONS

•GEO

Milsatcom - 2002?

DSP - ?

LEO

SBIRS Low - 2004

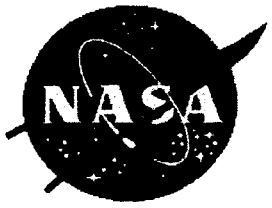
NPOESS - 2007

Surveill. Platforms

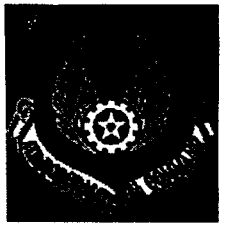
•AIRCRAFT

AVIATION - 2001

UAVs - 2001



MANAGEMENT APPROACH



PARTICIPATING ORGANIZATIONS/AGENCIES INCLUDE: NASA, AIRFORCE, BMDO, JIST.

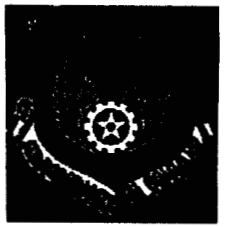
DEVELOP TWO SOURCES FOR MANUFACTURING CELLS AND BATTERIES

BUILD ON EXISTING COMMERCIAL TECHNOLOGY AND GOVT TECHNOLOGY DEVELOPMENT EFFORTS/PROGRAMS

TEAMING OF UNIVERSITIES, R&D ORGANIZATIONS AND BATTERY MANUFACTURING COMPANIES IS ENCOURAGED

NASA, AIRFORCE, NAVY LABS AND AEROSPACE PRIMES PARTICIPATE IN TECHNOLOGY EVALUATION FOR VARIOUS MISSIONS

TECHNOLOGY APPROACH



DEVELOPADVANCED ELECTRODE MATERIALS AND ELECTROLYTES TO ACHIEVE IMPROVED LOW TEMPERATURE PERFORMANCE AND LONG CYCLE LIFE

OPTIMIZE CELL DESIGN TO IMPROVE SPECIFIC ENERGY, CYCLE LIFE AND SAFETY

ESTABLISH MANUFACTURING PROCESSES TO ENSURE PREDICTABLE PERFORMANCE

DEVELOP AEROSPACE LITHIUM ION CELLS IN 5, 10, 20, 50, AND 200 AH SIZES

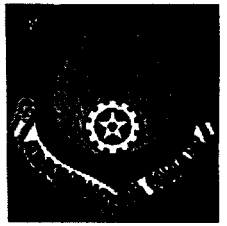
DEVELOP BATTERIES IN 28, 100 AND 270 V CONFIGURATIONS

DEVELOP ELECTRONICS FOR SMART BATTERY MANAGEMENT

DEVELOP A PERFORMANCE DATABASE REQUIRED FOR VARIOUS APPLICATIONS

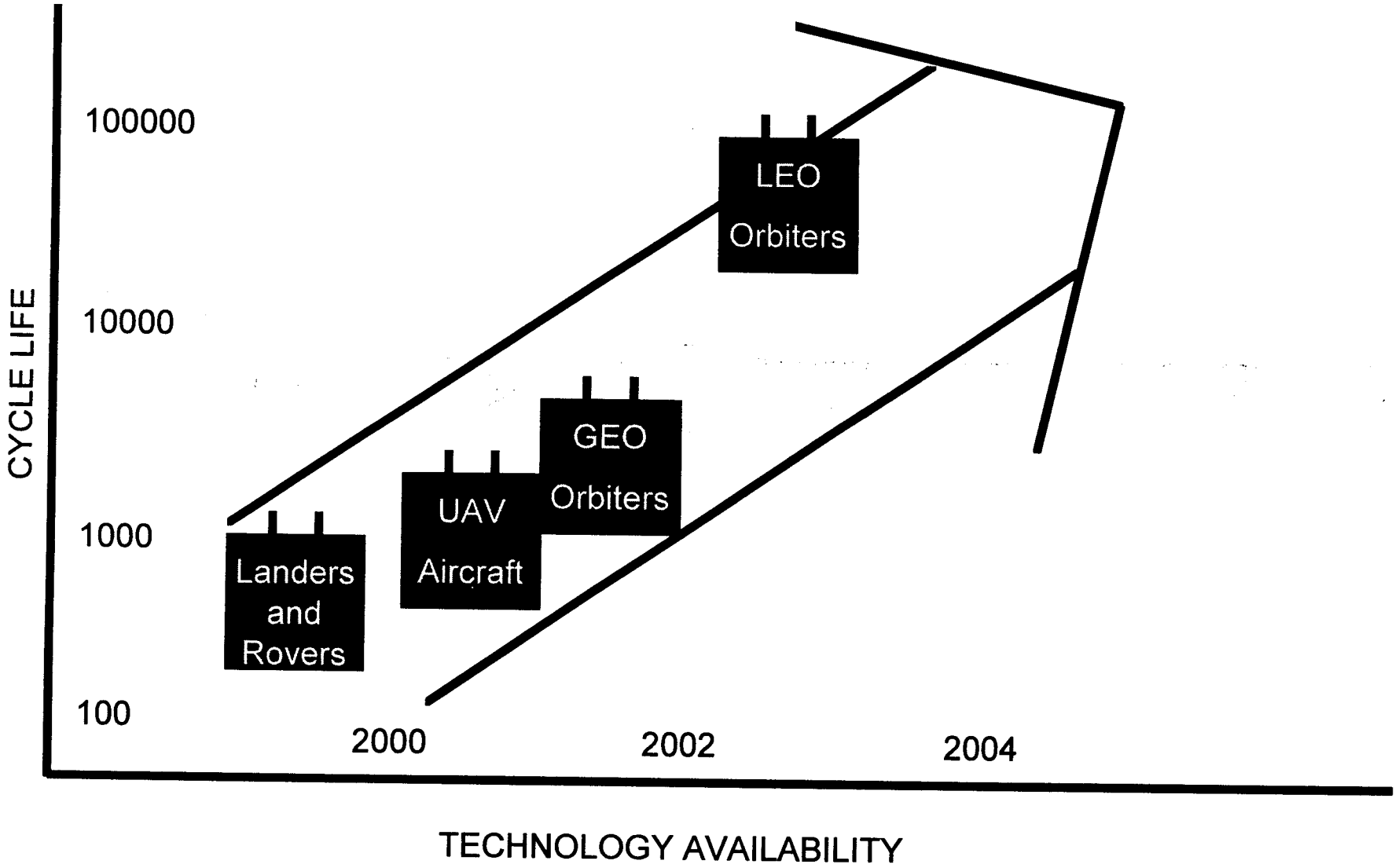
DEMONSTRATE TECHNOLOGY READINESS FOR VARIOUS NASA AND AIR FORCE MISSIONS

AEROSPACE LITHIUM-ION BATTERY PROGRAM ROADMAP



TASK	98 99 00 01 02 03 04	GOALS
CHEMISTRY & MATERIALS	LOW TEMP. AND STABLE E'LYTE HIGH CAP. & LONG LIFE ELECTRODES SEPARATOR OC/OD ADDITIVES	IMPROVE - LOW TEMP. PERF. - CYCLE LIFE - OPERATIONAL LIFE
CELL DEVELOPMENT	PROCESS DEV. DESIGN, AND CELL MANUFACTURING 10-20 Ah,500 CYC LT. HR, 200 Ah 40/50 Ah,2000 CYC 30000 CYCLE, 20-50 Ah	EST. MANF. PROCESS OPT. CELL DESIGN FAB. 10-200 Ah CELLS
BATTERY DEVELOPMENT	PROCESS DEV. DESIGN & MANF. LANDER/ROV UAV/AIRCRAFT GEO S/C LEO, PLANETARY S/C	EST. MANF. PROCESS DEV. SMART BATT. FAB. LANDER, ROVER GEO, LEO S/C, UAV AIRCRAFT BATT.
TESTING & QUALIFICATION	ELECTRICAL PERF., THERMAL, AND SAFETY TESTS 100/50% DOD LEO & GEO LIFE TEST FAILURE MODES & ANALYSIS	EST. DATA BASE DET. FAILURE MODES EST. CHARGE CNTLS DEMON. SAFETY
FLIGHT VALIDATION	LAND/ROVER UAV/AIRCRAFT S/C TOOLS GEO S/C LEO S/C	DEMON. TECH. FOR LANDER, ROVER GEO, LEO S/C, UAV AIRCRAFT MISSIONS

TECHNOLOGY DEMONSTRATION MILESTONES



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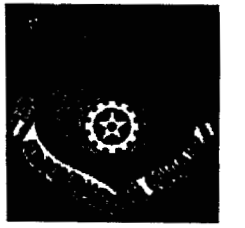

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